Overview of the LHCb Calorimeter Electronics

… focus in the ECAL/HCAL

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On behalf of the LHCb calorimeter group

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Calorimeter System

- **Requirements:**
  - Energy / Position measurements
  - Identification of hadrons, electrons, ?, p^0
  - L0 Trigger input (SPD/PRS/ECAL/HCAL):
    - High sensitivity & Fast response (40MHz)
  - No electronics pile-up (25 ns shaping)

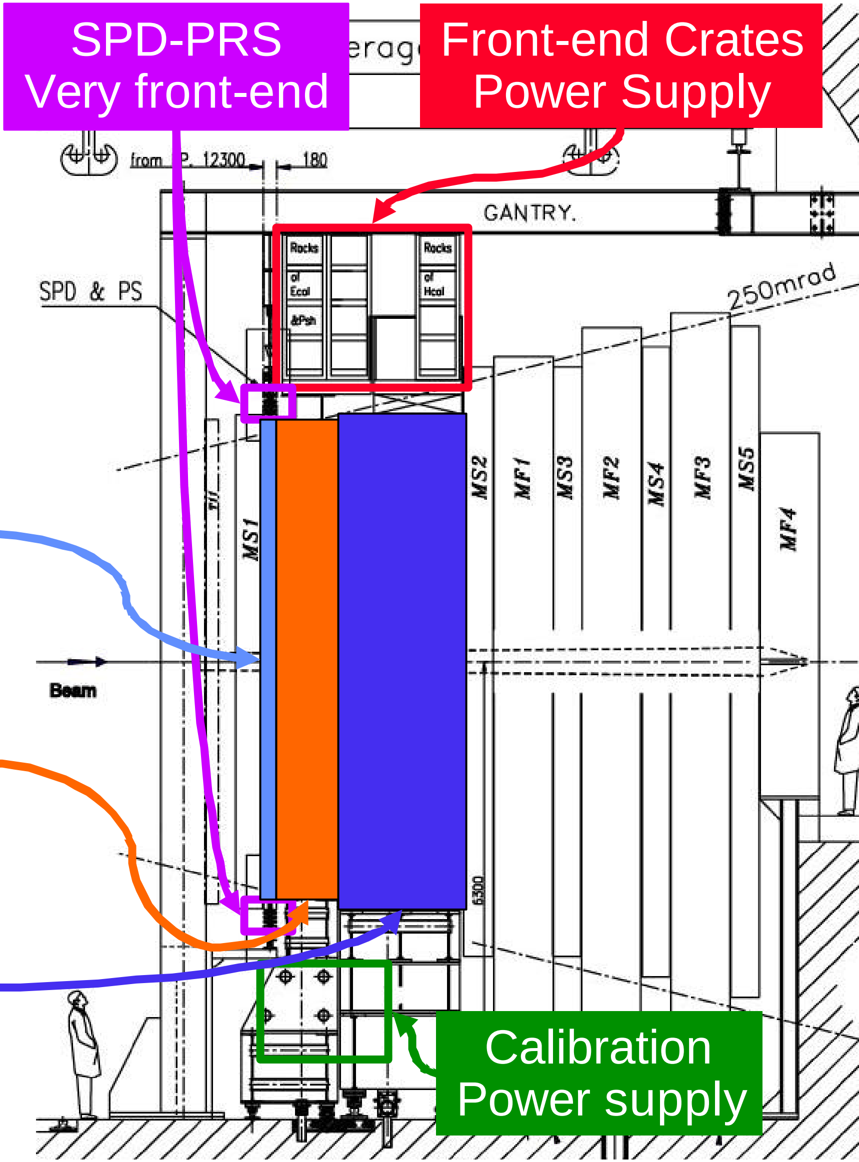
Front-end partly common
same crates

Scintillating Pad Det (SPD)
Preshower (PRS)
Scint. Pad + Fibres+ MAPMT
5953 cells each

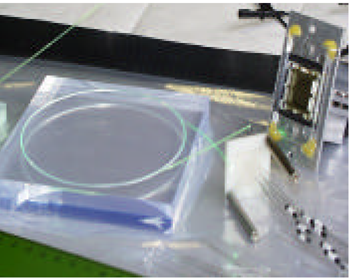
same electronics
same crates

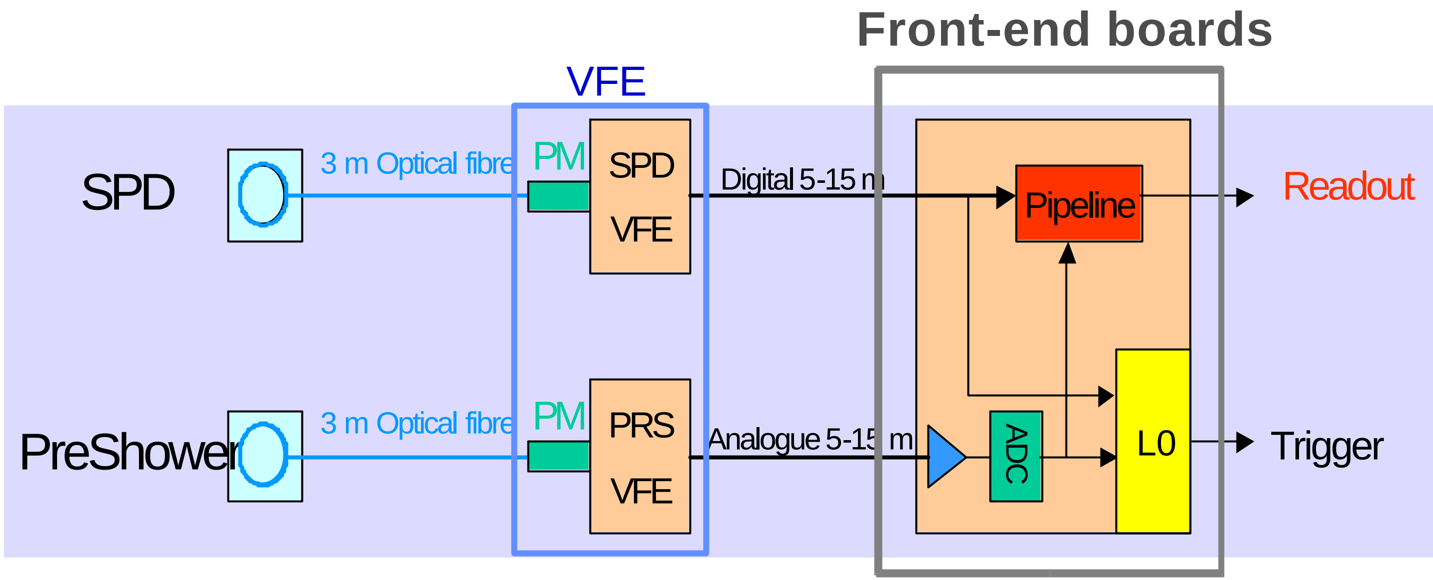
ECAL
Shashlik (Pb-scint.)
5953 cells

HCAL
Tiles (Iron-scint.)
1468 cells

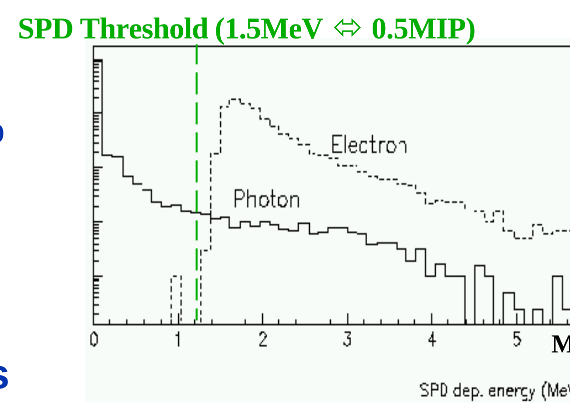


Electronics Overview: SPD - PRS





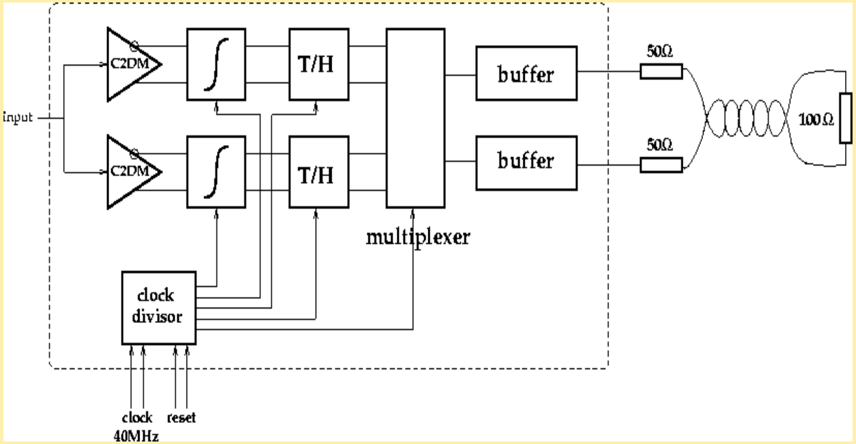
- **Light transporter by clear fibers to 64 anode PMT**
  - very front-end away from beam : no radiation problem
- **Dynamic range : 0 – 100 MIPs and accuracy required ~ 10%**
  - PRS : electron/pion separation → 10 bits
  - SPD : photon/mip separation → 1 bit
- **20 – 30 photo-electrons per MIP ® large fluctuations**
- **25 ns integrator mounted on the PMT – Reset with switches**
  - Cheap and maximum use of the photo-electrons
  - Potentially more sensitive to noise, drift of pedestal and switch time versus beam crossing



SPD and PRS ASIC

- **25 ns integration contains ~80% of the charge**
- **Two parallel integrators running at 20MHz and multiplexed at the output**
- **Differential chips**
- **Need to remove ~20% of the previous sample**

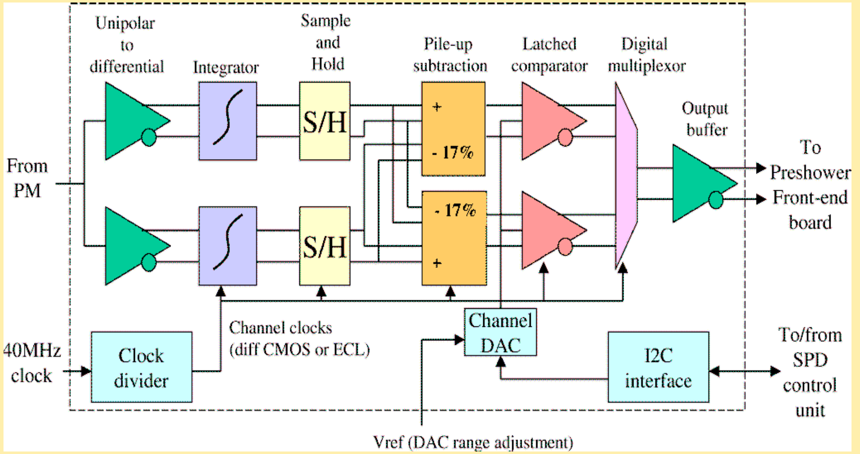
PRS



- **LSB is fixed to 1/10 of MIP**
  - Proper precision
  - Dynamic coverage
- **The integrator drives a 10bit ADC**

See following talk by Stéphane Monteil…

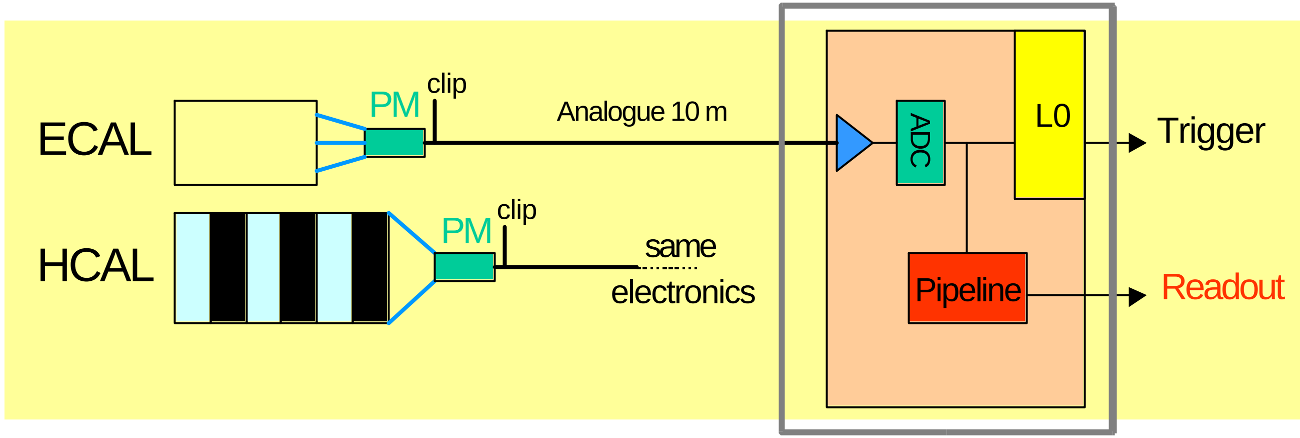
SPD



- **Threshold is low and need to remove 20% of previous sample**
- **Threshold comparison**
- **Digital Output (one bit)**
  - LVDS serializers

Production Readiness Review passed

Electronics Overview ECAL - HCAL



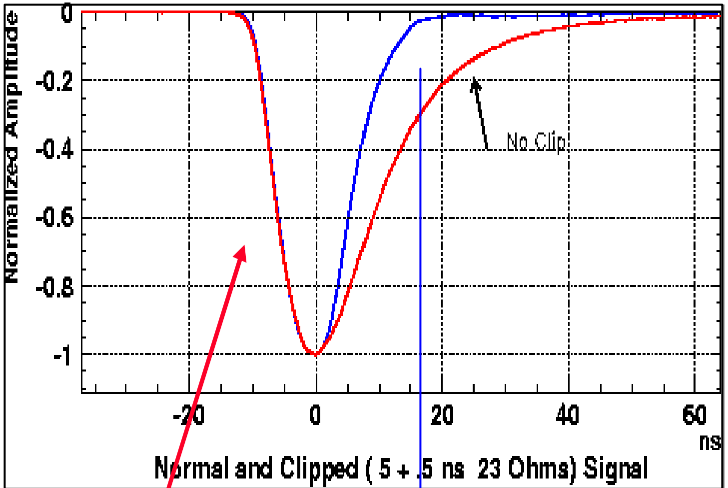
- **PMT are located (partly) in high radiation area (0.4Mrad/year)**
  - Signal transported to shaper/integrator by coax cable

- **Dynamic range is 0 - 10GeV/c (Et)**
- **ECAL resolution: 10%/ÖEÅ1%**
- **HCAL resolution: 80%/ÖEÅ10%**

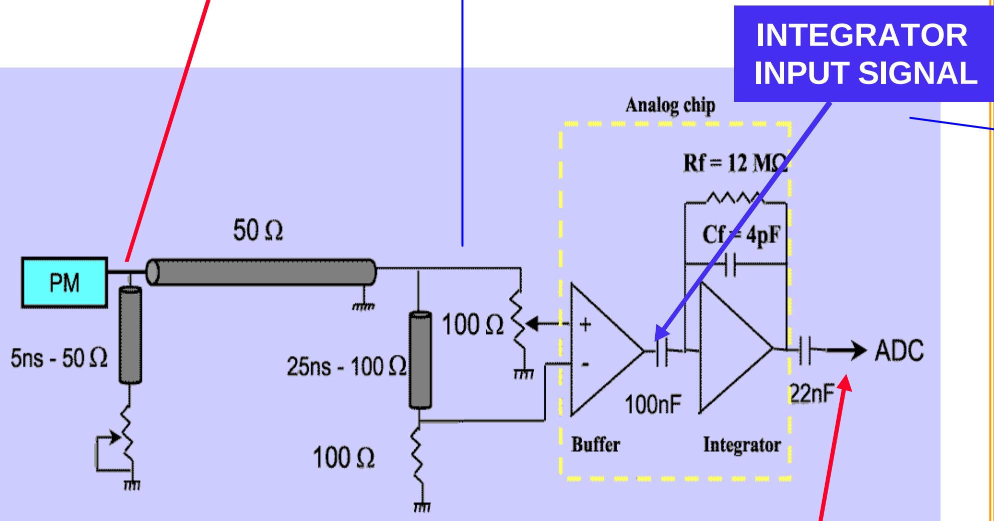
12 bit ADC
Noise max require ~ 1 ADC

- **Typically 500-1000 photo-electrons / GeV (50) in ECAL (HCAL)**
  - PM pulses shaped to 25ns before integration (delay line clipping)

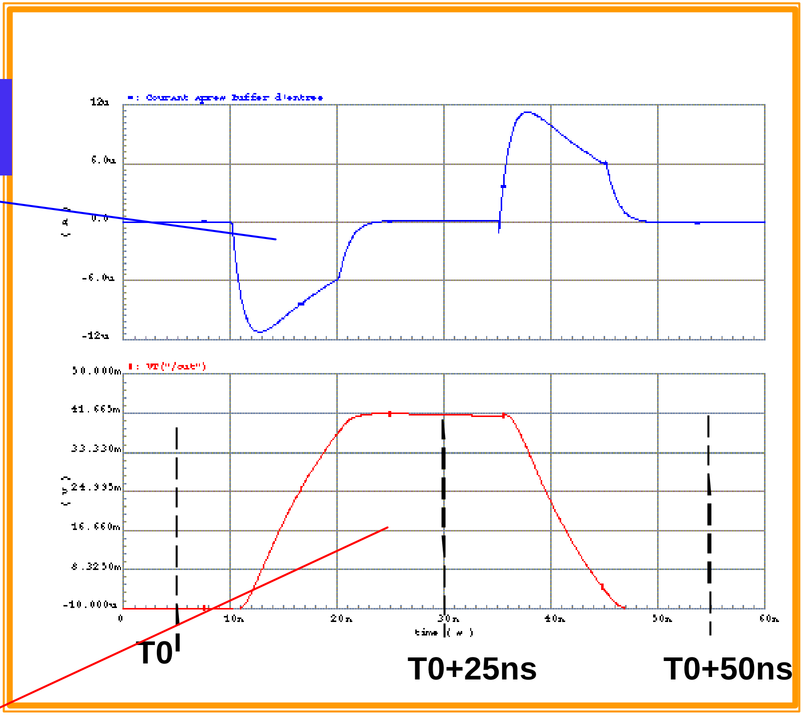
ECAL – HCAL ASIC



- **Shaping and integration**
  - Pulse shaping in 25 ns
  - Residue < 1% after 25 ns
  - Integrator plateau : 4 ns
  - Linearity < 0.5%
  - Rise time ~ 5 ns



Already produced and tested



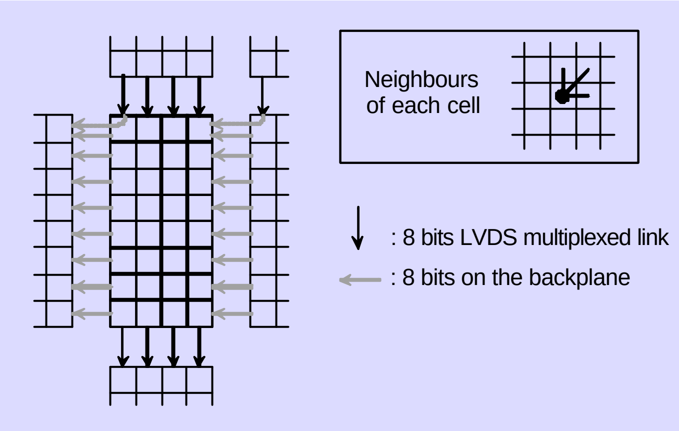
ADC INPUT SIGNAL

Level 0 trigger

- **Level-0 trigger : Hardware system**
  - Pipelined operations, fully synchronous, with fixed latency (4µs)
  - Reduce rate from 40MHz to 1MHz
  - Detector used : Vertex detector, Muon and Calorimeter (SPD, PRS, ECAL and HCAL)

- **Select High Pt particles**
  - Because of the B meson high mass, at least one decay particle has a high Pt (several GeV/c)

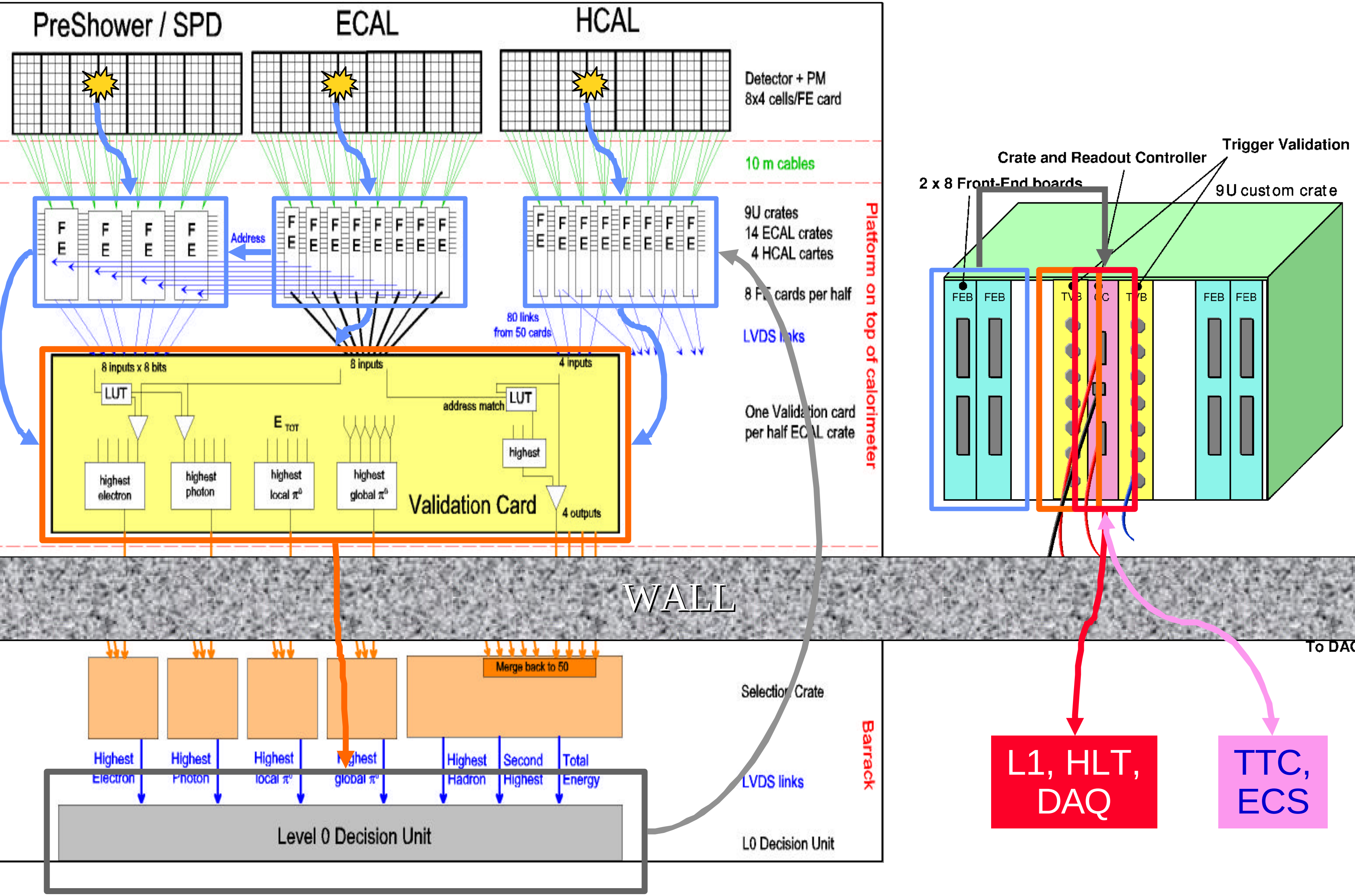
- **Calorimeter trigger works for**
  - electron, photon and neutral pions : ECAL deposits
  - Hadrons : HCAL deposits
  - SPD-PRS : particle identification



- **Logic based on Et on 2x2 cell area**
  - Value converted to 8 bits and sum cell Et
  - Access neighbours
    - Either from the same board
    - Or connect several boards/crate : dedicated backplane for connections
  - Keep only the highest local Et deposit

- **Calorimeter used to reject busy events at the trigger level : SPD multiplicity**

Trigger and readout architecture

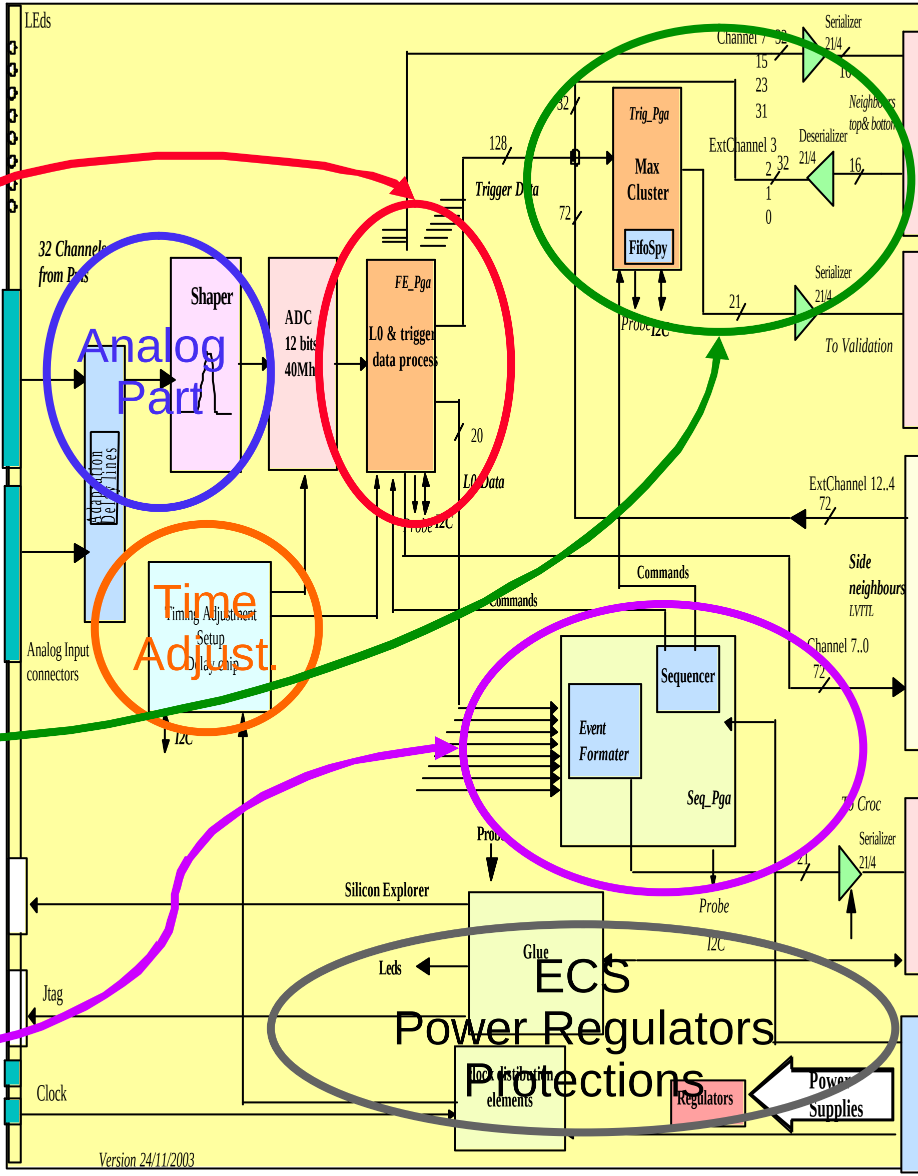


ECAL – HCAL: Front-end digital electronics

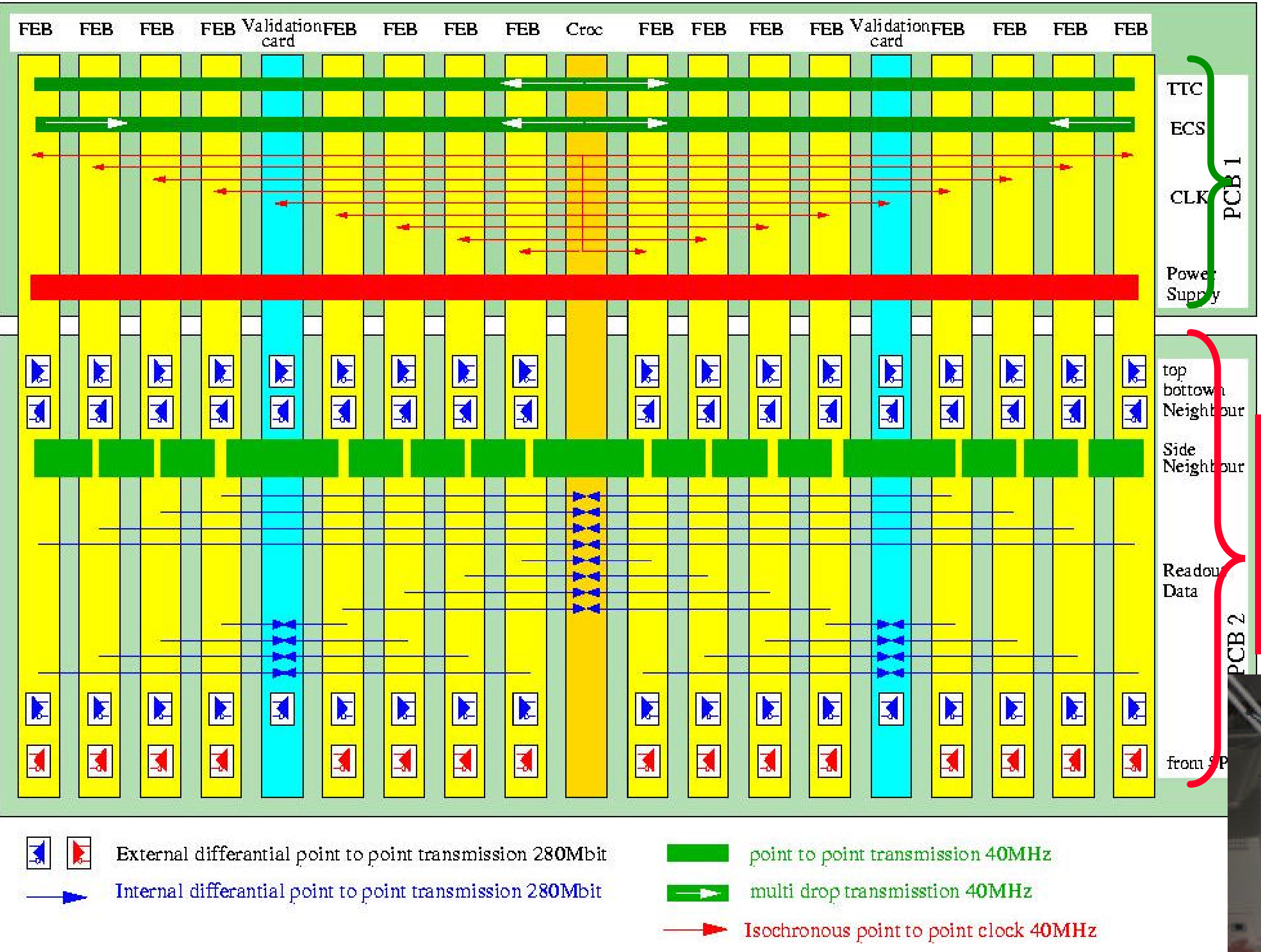
Digital data treatment (x8/x4):
- Channel synchronisation
- Pedestal correction
- Trigger 8-bit generation:
  - Calibration
  - 5 GeV/c saturation
- Data:
  - L0 latency (256 deep)
  - Derandomizer (16 deep)

Trigger data treatment:
- Send to neighbours
- Receives from neighbours
- Make 2x2 sums
- Sends maximum

Event Builder – Control :
- Header (evt id, evt type, …)
- 32 channels
- Trailer (parity, …)



Dedicated backplane



ECS
Power Supply
Clock

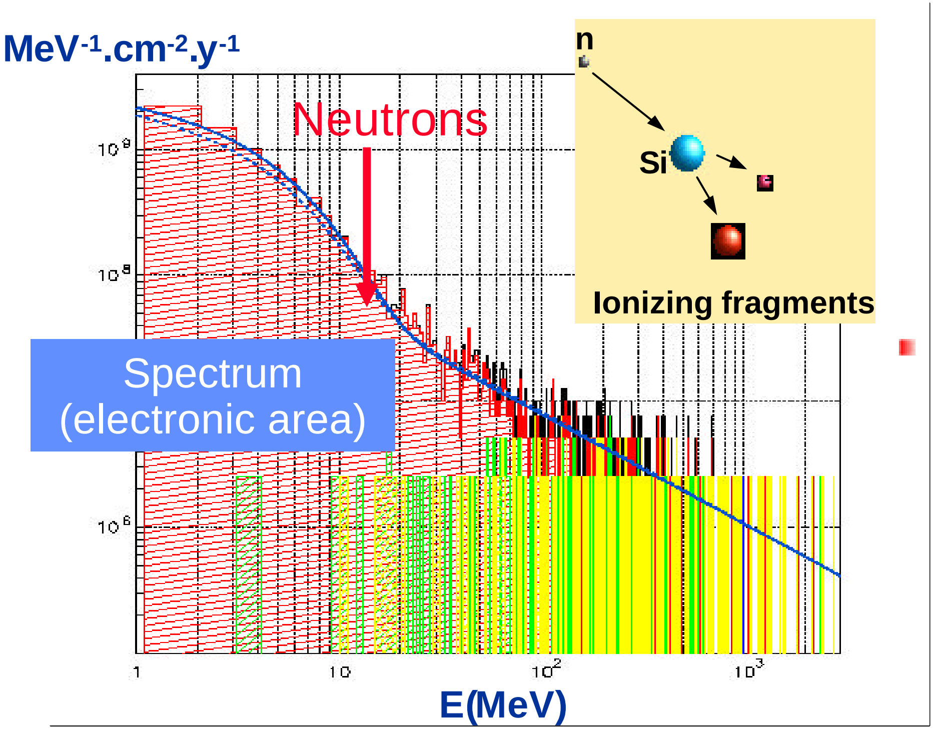
Trigger
Readout

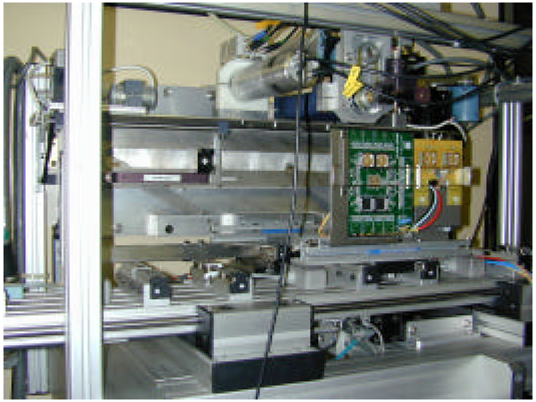
Boards/crate
interconnection

Radiation problems

- **Potential problems:**
  - Accumulated doses (200 rad/year at the level of the racks) : 2krad in 10 years
  - Single Event Effects (SEE):
    - Single Event Upset (SEU) – bit-flip in re-programmable FPGA/RAM
    - Single Event Latchup (SEL) – possibly destructive “short-circuit”

- **In LHCb, main worry comes from neutron flux**





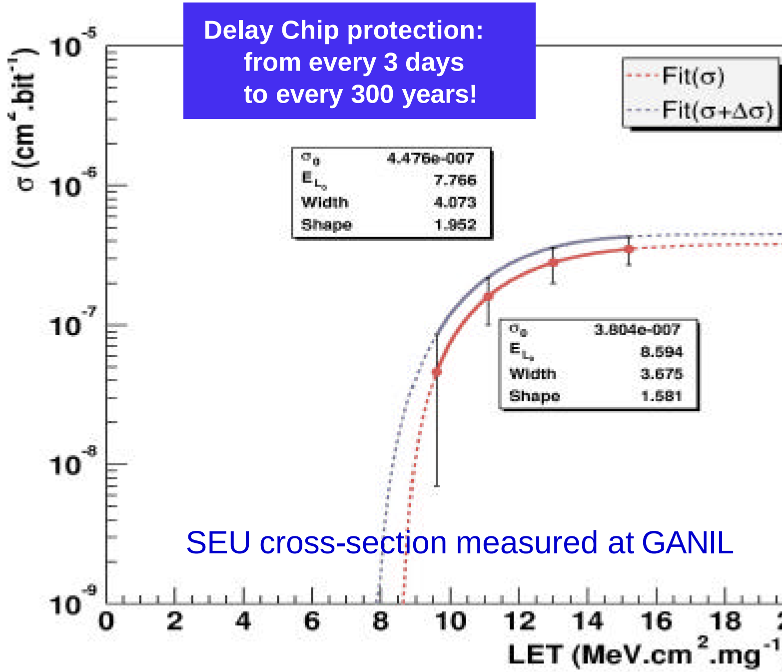
- **Components have been irradiated**
  - Centre de Proton-Thérapie (Orsay)
    - Proton ($10^8 cm^{-2}.s^{-1}$,200MeV)
  - GANIL (Caen): Heavy Ions
    - Krypton, 73MeV/A & 58MeV/A, ($10^5 cm^{-2}.s$

Very efficient: the fragment is directly sent through the component !

rradiation tests

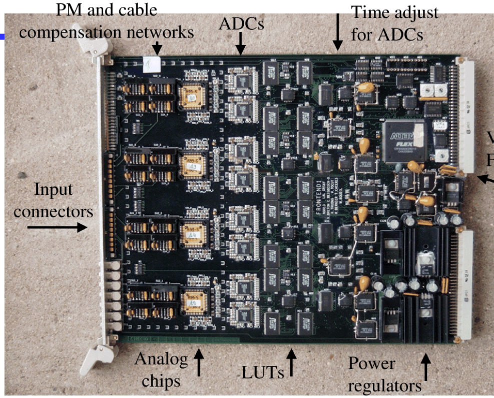
- **Typical dose effects starts to be observed only after 50 krad** ? OK !

- **SEU quite easily observed**
  - Protections implemented :
    - Registers are protected
      - Triple Voting (majority vote among three copies of the register)
      - Parity bit coded in the data
    - FPGA configuration protected intrinsically
      - Anti-fuse FPGA (ACTEL)



- **SEL have been observed with typical flux corresponding several LHCb years**
  - Very pessimistic assumptions included in the rate estimations
  - Never been destructive
    - power cycle
    - use MAX power switch component (tested at GANIL!

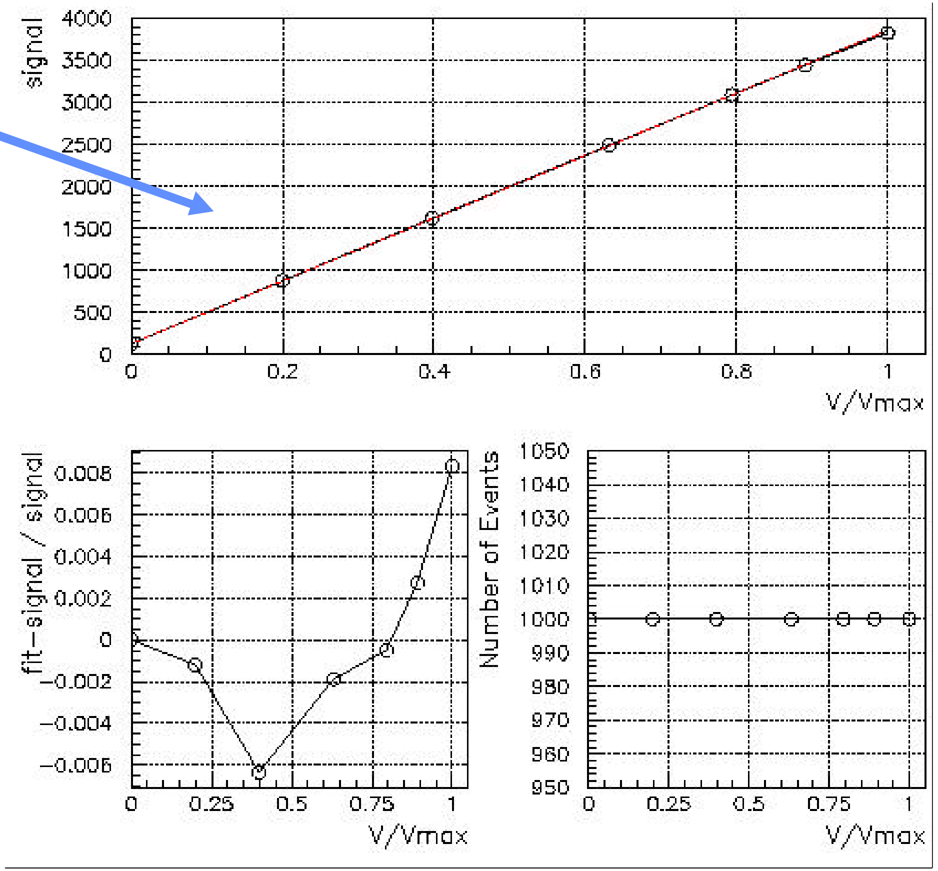
ECAL – HCAL electronics performances



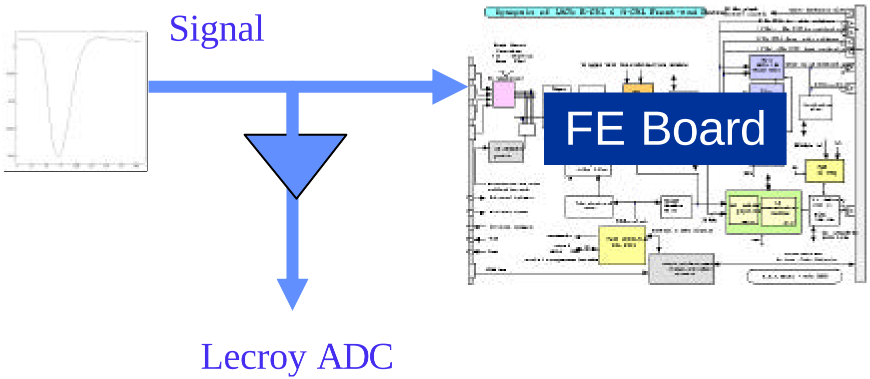
Performances have been tested with a prototype of the board

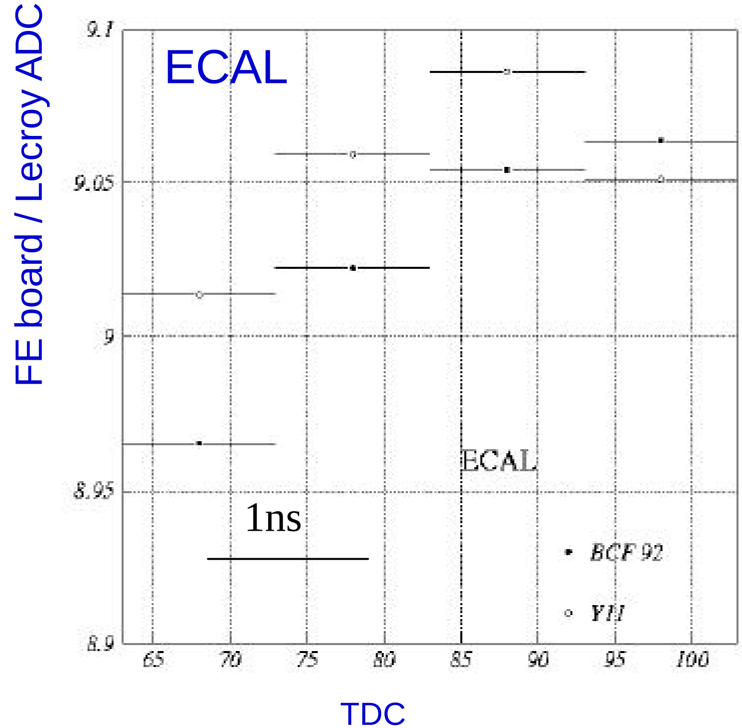
- at CERN (test beam)
- on a dedicated test bench

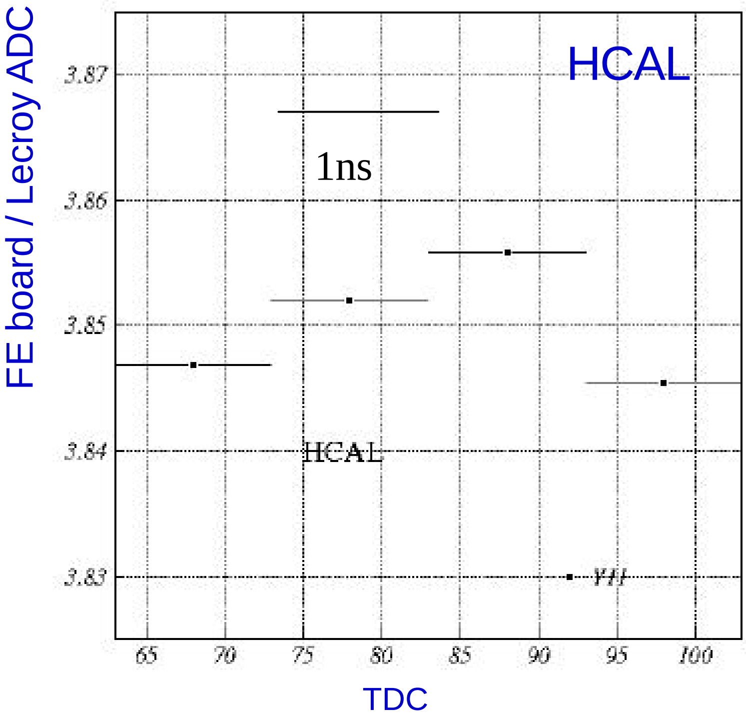
	Simulation results 50°C	Test results
Dynamic range	1,4V 1,5V	1,4V 1,6V
Non linearity	+/-0,5% +/-1%	+/-0,4% -1%
Residue after 25ns	<0,5%	<1%
RMS noise after subtraction	160uV over 250 ohms	220uV over 250 ohms
Integrator gm	31mA/V	18mA/V
Fall time	5.5us	2us
Rise time	4ns	6ns
Integrator Rin	190 Ohms	270 Ohms
Integrator Open Loop gain	65dB	65dB
Crosstalk	<0,4%	<0,6%
Power Consumption	60mW / channel	57mW / channel



ECAL – HCAL electronics performances

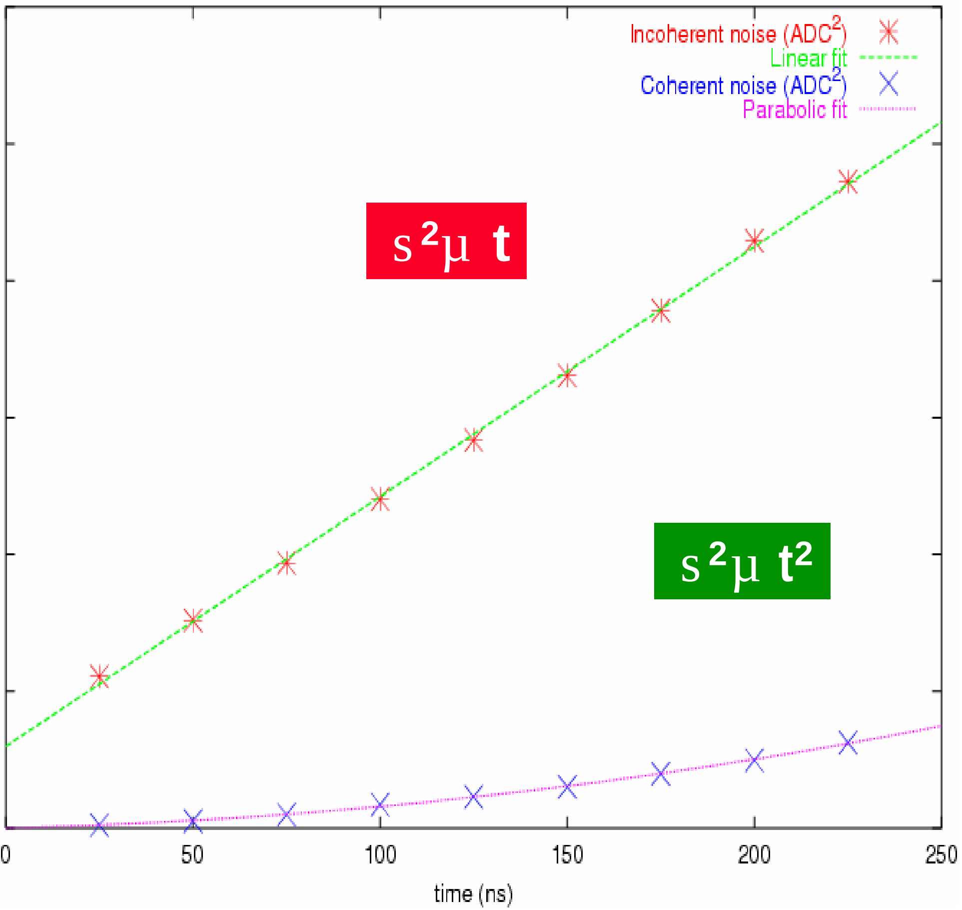






- **Test beam results**
  - By comparing FE and Lecroy (long int.)
    - Linearity measurements
  - Taking into account particle time arrival in the coincidence window
    - Plateau width/shape effects (<1%)

Electronics performances : noise



- **Noise measured from 10 consecutive (40MHz) samples (no input signal)**

- **Incoherent noise ($\sigma^2 \propto t$)**

Intrinsic ADC noise

σ^2 (t) = 0.60 + 0.02 x t ADC^2

- **Coherent noise** ($\sigma \propto t$)

σ (t) = 0.08 + 0.5 x 10^{-2} x t ADC

Extrapolation to a typical 3x3 cluster :

Coherent noise : 3.5 ADC
Incoherent noise : 2.4 ADC

LHCb

Conclusion

- **SPD, PRS and ECAL/HCAL are specific detectors**
- **Provide L0 input for trigger decision**
- **Three ASIC have been designed for the readout of the four Detectors**
  - SPD $\rightarrow$ Barcelona
  - PRS $\rightarrow$ Clermont-Ferrand
  - ECAL/HCAL $\rightarrow$ Orsay

  AMS 0.8u BiCMOS technology
- **Common system wherever possible**
  - Digital electronics design (front-end board) partly common
  - Same crate with a dedicated backplane for trigger treatment
- **Components have been tested for irradiation**
  - Dose is OK – SEE protection taken into account in the design
- **Electronics fulfill requirements**
- **Front-end board series production in automn 2004**